ELECTRICAL AND MICROPHYSICAL RESPONSES TO SALT SEEDING IN WARM MARITIME CUMULUS CLOUDS

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Electrical, microphysical and dynamical responses to salt seeding have been investigated during cloud seeding experiments in several parts of India. Following massive salt seeding, increases in cloud temperature by 1 to 2 Celsius and cloud liquid water content up to 200 percent were observed in warm cumulus clouds (Ramahandra Murty et a., 1975, 1976). Cloud drop size distributions in seeded warm cumulus clouds increased in mean volume diameter up to 478 percent and computed liquid water content increased upward of 60 percent (Kapoor et al., 1976). In maritime warm cumulus clouds, which developed rain following seeding, the electric field reversed from initial negative to positive, occasionally preceded by intensification (Ramachandra Murty et al., 1976). This field reversal was attributed to the transport of large positive charges, from upper cloud levels to the base, by raindrops which form initially at higher levels in vigorous updraft regions. The prior intensification was attributed to updraft invigoration produced by massive salt seeding, since electrical activity is closely associated with convective activity (Latham and Stow, 1969).

In 1979, measurements on point discharge current, cloud liquid water content, cloud drop size distributions and in-cloud temperature were made at Bombay (18^{0} 15'N, 72^{0} 49'E, 11 m ASL) in warm cumulus clouds before and after their seeding and also in randomly chosen control clouds using a DC-3 instrumented aircraft. All clouds were in the Arabian Sea, 20 to 40 km off the coast of Bombay.

Corona discharge current was measured by a static discharge probe fitted on the tail of the aircraft with a suitable teflon insulator (Selvam et a., 1976). Liquid water content was measured by a JW-hot wire meter (Ramachandra Murty et al., 1976). Cloud drop size distributions were measured using a droplet sampler containing glass slides (Kapoor et al., 1976).

Three to nine traverses were made in each of four pairs of seeded (target) and non-seeded (control) clouds (Table 1). The first three traverses were non-seeded, even in target clouds. Observations in non-seeded tranverses of target clouds were compared with those from subsequent seeded tranverses.

The corona discharge current in clear air was less than the detection limit of the instrument (± 0.14 A). No corona current was observed in clouds less than 3000 ft. thick. In thicker clouds, a positive corona discharge current was found upon entry; it increased with cloud thickness and liquid water content. Positive electric fields were found at the bases of warm cumulus clouds (Selvam et al., 1976).

Following seeding, cloud liquid water content increased up to 113 percent and corona discharge current increased up to 400 percent (Fig. 1). In the first three of six cloud traverses on 6 Sept. 1979 no seeding was carried out. In traverses 4 to 7 a salt mixture totalling 300 kg was released into the cloud. The liquid water content and the corona discharge showed marked increases following seeding (traverses 4 to 6 in Fig. 1) compared to the values recorded in the non-seeded traverses 1 to 3. Such marked increases were not observed in any control clouds (Table 1).

In-cloud temperatures increased following seeding in all four target (maximum + 1.2 Celsius), whereas a decrease (maximum -1.4 Celsius) was noted in three of four control clouds, with the fourth warming only 0.1 celsius. These results are in agreement with those obtained from the clouds in the Poona region (Ramachandra Murty et al., 1975). Following seeding the droplet spectra broadened, with a maximum increase in mean volume diameter of about 250 percent. Such features were absent in control clouds.

CONCLUSIONS

During salt seeding experiments near Bombay during the 1979 summer monsoon:

1) corona discharge currents were not found in clouds less than 3000 ft. thick, but were positive in thicker clouds;

2) increases in cloud liquid water content up to 113 percent and corona discharge current up to 400 percent followed seeding in target clouds, but no such marked increases were found in control clouds;

3) in-cloud temperatures increased up to 1.2 Celsius following seeding in all four target clouds but decreased as much as 1.4 Celsius in three out of four control clouds with the fourth warming only 0.1 Celsius; and

4) cloud droplet spectra broadened following seeding, with increases of up to 250 percent in mean volume diameter, but no such increases were found in control clouds.

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Table 1. Radar data of seeded (Target) and non-seeded (Control) clouds.

Cloud Target or Control	T	C	T	C	T	C	T	C
Azimuth (degrees)	280	292	268	297	280	256	315	320
Range (km)	56	77	90	67	95	75	42	59
Time seeding began	1630	-	1716	-	1603	-	1145	-
Time seeding ended	1640	-	1729	-	1620	-	1200	-
Salt used (kgs)	175	-	125	-	300	-	175	-
Total traverses	9	9	7	3	7	4	6	6
Seeding traverses	3-9	-	3-7	-	3-7	-	3-6	-
Areal echo coverage (km^2) at first echo time	10.0	8.2	7.3	9.1	21.8	2.7	8.7	5.8
Time (IST) of first echo	1632	1632	1650	1718	1536	1622	1155	1158
At first traverse	0.0	12.2	21.6	0.5	12.6	8.7	0.0	0.0
At start of seeding	0.0	-	16.4	-	17.4	-	0.0	-
At end of seeding	8.4	-	9.8	-	5.7	-	3.2	-
Maximum	13.7	18.2	32.8	9.1	21.8	20.9	8.7	7.3
Height of echo-top (km)	1.2	2.2	3.5	2.0	4.0	3.0	NA	NA
When first observed (Time IST)	1634	1643	1658	1726	1538	1615		
At commencement of initial traverse	0.0	2.2	3.3	NA	4.1	2.2	NA	NA
At start of seeding	0.0	-	2.9	-	4.6	-	NA	-
At end of seeding	1.6	-	2.0	-	2.7	-	NA	-
Maximum	2.4	2.2	4.2	2.0	5.0	4.5	NA	NA
Total echo duration (min)	64	22	56	18	59	61	16	14

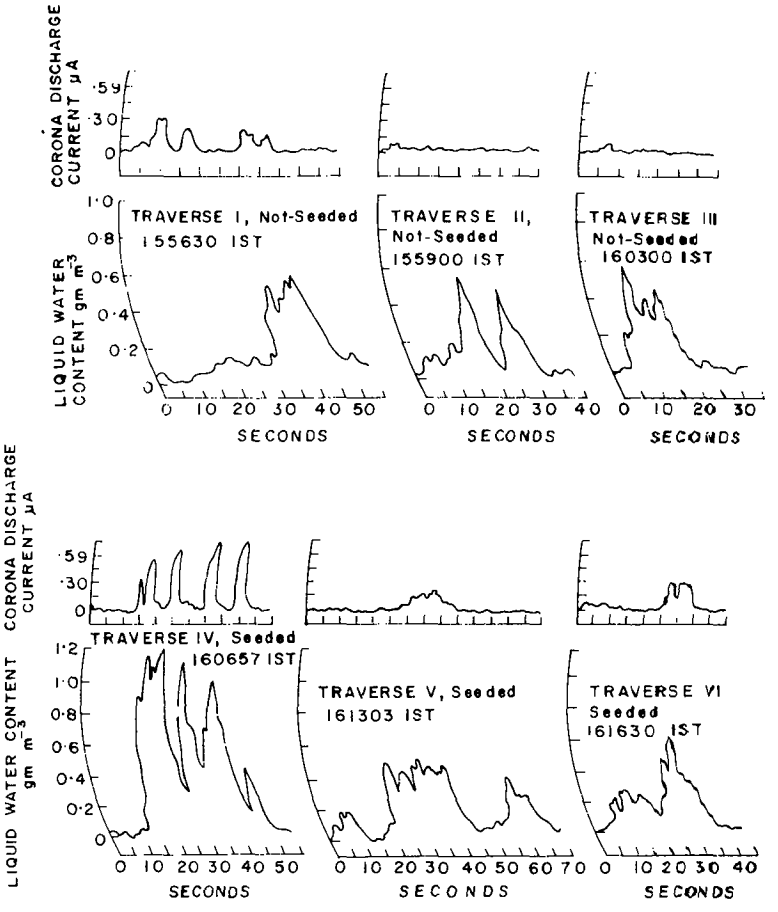

FIGURE 1 : CORONA DISCHARGE CURRENT AND LIQUID WATER CONTENT DURING SIX TRAVERSES (3 NOT-SEEDED, 3 SEEDED) IN AN ISOLATED CUMULUS CLOUD. 6 SEPT. 1979, NEAR BOMBAY, INDIA.